NERL Research Abstract

EPA's National Exposure Research Laboratory
GPRA Goal 3 - Safe Food
APM # 661

Significant Research Findings

First-Generation Multimedia, Multipathway Exposure Models

Scientific Problem and Policy Issues

The Food Quality Protection Act (FQPA) of 1996 requires EPA to consider aggregate human exposure to a pesticide, especially for infants and children, when setting regulatory limits on its usage. Aggregate exposure is the total exposure of humans to the pesticide from all uses and through various pathways and environmental media. These include dietary ingestion of pesticide residues in food and water, inhalation of air containing pesticides, dermal contact with surfaces containing pesticides (indoors and residential lawns), and non-dietary ingestion of pesticide residues from hand- or object-to-mouth activities. Estimation of the population's exposure from dietary ingestion and inhalation is difficult because of the lack of information on human activity patterns and food consumption, limited knowledge of contaminant levels in food, and challenges in determining breathing rates for different levels of human activity. Dermal and non-dietary exposure pathways are challenging to quantify because many factors that are difficult to measure (such as the frequency of contact with contaminated surfaces, the subsequent transfer from those surfaces, and the frequency of putting fingers and objects into one's mouth) influence exposure. These issues result in both variability of exposures to individuals within a population and uncertainty in exposure estimates. Hence, a probabilistic model that predicts the range and distribution of personal exposures and doses within a population as well as the uncertainty in the model estimates was developed. The model is called the Stochastic Human Exposure and Dose Simulation Model for Pesticides, or SHEDS-Pesticides.

Research Approach

The primary objective of this research is to develop a computerized model for conducting assessments of aggregate pesticide exposure and dose. As an example, the model is demonstrated by an assessment for the insecticide chlorpyrifos. Chlorpyrifos has been widely used in homes and on food crops, and is associated with multiple media and pathways of human exposure.
The aggregate SHEDS-Pesticides model is being developed in stages. The first was development of the residential SHEDS-Pesticides model that focused on children's exposure and absorption via dermal contact with and non-dietary

ingestion of surface residues in and around the home. Distributions of exposure, mass of 3,5,6 -trichloro-2-pyridinol TCP (a urinary metabolite of chlorpyrifos) in blood, and the amount of TCP eliminated in urine were modeled for different residential uses of chlorpyrifos, different times after application, and different age groups of children that might be exposed. The second stage has involved combining the Residential-SHEDS results with a probabilistic, multimedia, multipathway exposure model and chlorpyrifos assessment developed as part of the National Human Exposure Assessment Survey (NHEXAS). Pathways included in the NHEXAS model were inhalation of indoor and outdoor air, dietary ingestion, non-dietary ingestion of dust, and non-dietary ingestion of soil. This assessment simulated distributions of daily aggregate and pathway-specific chlorpyrifos absorbed into the body for the general population of Arizona and for children aged 3 to 12 years residing in Minneapolis-St. Paul, MN. Combining these two modeling assessments yielded initial estimates of aggregate exposure and absorbed dose for short and longer term post application time periods.

Results and Implications

Results from the Residential-SHEDS modeling study indicate that dermal absorption was the major contributor to dose for time periods soon after application (less than a week or month). Younger children (0-4 years old) had higher exposures and doses than older children (5-9 years old) because of differences in assumed activity patterns. Contact with smooth surfaces caused higher exposure than contact with textured surfaces such as carpets because of greater transfer efficiency to skin from smooth surfaces. Model results of metabolite in urine are of the same levels as published data from other studies, suggesting that the model estimates are realistic.

The NHEXAS chlorpyrifos model results suggest that for longer times after application, the major route of chlorpyrifos intake is food ingestion, followed by dust ingestion and indoor air inhalation. High variability in modeled absorbed doses primarily reflects differences in activities of the children and differences in the concentrations contacted by individuals during their daily activities. When the NHEXAS Arizona and Minneapolis-St. Paul data become available, they can be compared to the modeled distributions. When considering all the time periods after application within a year, inhalation and dietary ingestion routes dominated for the average population, and dermal and non-dietary ingestion routes dominated for the higher exposed persons, corresponding to recent pesticide applications. The estimates for the most highly exposed were found to be very sensitive to pesticide usage information (i.e., assumed probability of a broadcast versus a crack and crevice application). Preliminary analyses reveal that uncertainty in model results stems from lack of data for critical factors, including: information on pesticide usage; the pattern and frequency of touching surfaces; hand- and object-to mouth activity patterns; environmental concentrations and pesticide residue concentrations at different

post-application times, and; factors related to intake and uptake into the human body after exposure. The development of this first-generation aggregate model, with many built-in assumptions, is still at an early stage. Nevertheless, these preliminary results help researchers to better understand the events and factors that lead to pesticide exposure. As development progresses, the model will help refine identification of areas of greatest uncertainty that need more research.

This research project directly supports ORD's research to improve the scientific foundation of human health risk assessment under the GPRA Goal 8.2.1, Annual Performance Measure (APM) 661 (Develop first generation multimedia and multipathway exposure models for infants, children, and the general populations). It will help the program offices improve the risk assessment and risk management processes by providing more realistic exposure assessment methods than currently used screening level methods. The SHEDS-Pesticides model will help users test hypotheses and formulate appropriate designs for exposure measurement studies. This work also directly addresses GPRA Goal 3.2.4 (Safe Food, Research to Support New Regulatory Requirements under FQPA), APM 680 (First Generation Multimedia, Multipathway Exposure Model for Infants and Young Children and the ID of Critical Exposure Pathways and Factors). The probabilistic modeling approach used by SHEDS-Pesticides can aid the determination of whether for a given pesticide "there is a reasonable certainty that no harm will result from aggregate exposures to the pesticide's chemical residue from all anticipated dietary sources as well as all exposures from other sources for which there are reliable information," as required by FQPA. SHEDS will help to improve quantification of infants and children's exposure and dose to pesticides and provide a framework for identifying and prioritizing measurement needs under FQPA.

Research Collaboration and Publications

The SHEDS-Pesticides modeling project was conducted primarily by a team of NERL staff scientists. EPA's Office of Pesticide Programs cooperated and provided technical input. Contractor assistance in writing computer programs was provided by ManTech Environmental Technology, Inc. and independent consultant Dr. Jianping Xue. Professor Robert Buck, University of Michigan, provided contractor assistance in developing model inputs based on available data. This research has been presented in several international and national conference presentations, and in the manuscripts that follow.

Zartarian, V.G., Özkaynak, H., Burke, J.M., Zufall, M.J., Rigas, M.L., Furtaw, E.J., Jr. A modeling framework for estimating children's residential exposure and dose to chlorpyrifos via dermal residue contact and nondietary ingestion. *Environmental Health Perspectives* 108: 505-514, 2000.

Buck, R.J., Özkaynak, H., Xue, J., Zartarian, V.G., Hammerstrom, K. Modeled estimates of chlorpyrifos exposure and dose for the Minnesota and Arizona NHEXAS populations. *Journal of Exposure Analysis and Environmental Epidemiology*. Submitted.

Future Research

The first-generation multimedia, multipathway exposure models described here are part of a larger on-going effort to develop models that improve our understanding of the pathways and factors that contribute to pollutant exposure and dose, especially to infants and children. The aggregate SHEDS-Pesticides model is being modified to include daily time profiles of exposure, absorbed dose, and eliminated dose via the inhalation, dermal, dietary, and non-dietary ingestion routes for discrete time periods post-application. Research will be conducted to extend these daily cross-sectional profiles to longitudinal profiles (e.g., monthly or annual profiles) that account more accurately for accumulation of pesticides in the body. Work is also being conducted to refine the dose aspects of the model using the dose estimating exposure model being developed in NERL. That research will help SHEDS-Pesticides to better simulate the body's uptake, metabolism, and elimination of pesticides. Additional exposure pathways such as contact with residues on pets and track-in of pesticides into the home on shoes and clothing will also be included in SHEDS-Pesticides, and new measurements data will be used to refine the model inputs and evaluate the model outputs. In addition, a user-friendly interface is being developed for the aggregate SHEDS-Pesticides model.

Questions regarding NERL's human exposure and dose modeling research can be directed to:

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